MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EME2146 – APPLIED THERMODYNAMICS
(ME)

27 FEBRUARY 2017
2.30 p.m. - 4.30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of six pages (including the cover page) with four questions and an Appendix.
2. Answer ALL four questions.
3. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
4. Write all your answers in the answer booklet provided.
5. A property table booklet is provided for your reference.

Question 1

A rigid vessel contains non-reacting mixtures at 100 kPa and 80 °C. The mixture consists of 8.4 kg of nitrogen gas (N_2), 3.2 kg of oxygen gas (O_2), 2.2 kg of carbon dioxide gas (CO_2), and 0.9 kg of water vapor (H_2O).

Substance	N_2	O_2	CO_2	H_2O
Molecular weight (kg/kmol)	28	32	44	18

Assuming ideal gas behavior of the gaseous mixtures and taking the universal gas constant, $R = 8.314$ J/mol·K and constant pressure specific heat, $c_p = 29.099$ J/mol·K, determine

a. the mass fraction of each component, [4 marks]

b. the number of mole of each component in kmol, [4 marks]

c. the mole fraction of each component, [4 marks]

d. the volume of the vessel in m^3, [3 marks]

e. the absolute humidity of the mixture, [3 marks]

f. the relative humidity of the mixture, and [3 marks]

g. the amount of heat transfer to cool the rigid vessel from 80 °C to 70 °C in kJ. [4 marks]

Continued…

Question 2

Propane (C_3H_8) is burned with 100 percent excess dry air during a steady-flow combustion process. Both the propane and air enter the combustion chamber at 25°C. The mixture is combusted completely at constant pressure of 1 atm. The products leave the chamber at 127 °C and 1 atm.

a. Find the balanced combustion equation.

[5 marks]

b. Find the air fuel.

[3 marks]

c. Determine the heat transfer for this process per unit mass of propane.

[9 marks]

d. In order to supply heat at a rate of 2000 kW, determine the required mass flow rate of the fuel.

[3 marks]

e. Find the dew-point temperature of the water vapor in the product.

[3 marks]

f. If the combustion process is conducted with 100 percent theoretical air, the amount of heat transfer for this process will be lower or higher? Briefly explain your answer.

[2 marks]

Continued...

Question 3

Consider an ideal Brayton cycle. Air enters the compressor at 27 °C and leaves at 277 °C. Air enters the turbine at 627 °C.

a. Assume variable specific heats, find the pressure ratio, net work out and thermal efficiency for this cycle.

[14 marks]

b. Assume constant specific heats at room temperature ($c_p = 1.005$ kJ/kg·K and $k = 1.4$), find the pressure ratio, net work out and thermal efficiency for this cycle.

[11 marks]

Continued...

Question 4

A large and frictionless piston-cylinder contains 1.4 kg of a gaseous pure substance. Piston expanded slowly from its initial volume, V_1 to the maximum volume, V_2 under constant pressure, $p_1 = 100$ kPa as shown in Figure Q4. The initial and final temperature are $T_1 = 400$ K and $T_2 = 300$ K respectively.

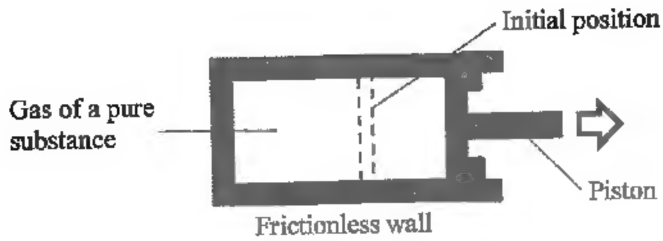

Figure Q4

For the range of the pressure and temperature, the substance is found to have the expansivity and the isothermal compressibility as:

$$\alpha_p = \frac{1}{T}\ ;\ \beta_T = \frac{1}{p}\left(\frac{p_0}{p + p_0}\right)$$

where the constant, $p_0 = 1.00$ MPa. The universal gas constant, molecular weight and specific heat ratio of the substance are $R = 8.314$ J/mol·K, $M = 28$ g/mol and $\gamma = 1.4$ respectively. The substance is behaved as an ideal gas when the pressure is relatively small, $p/p_0 \ll 1$.

a. Determine the equation of state of the substance. [12 marks]

b. Calculate the amount of heat transferred. [6 marks]

c. Find the initial volume. [2 marks]

d. Find the volume after expansion. [2 marks]

e. Calculate the change of internal energy. [3 marks]

Continued...

APPENDIX

A1. Clayperon Relation:

$$\frac{dp_{sat}}{dT} = \frac{s_{fg}}{v_{fg}} = \frac{h_{fg}}{Tv_{fg}}$$

A2. Maxwell Relations:

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v ; \quad \left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$$

$$\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T ; \quad \left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$

A3. Change of internal energy, enthalpy, and entropy:

$$u_2 - u_1 = \int_{T_1}^{T_2} c_v dT + \int_{v_1}^{v_2} \left[T\left(\frac{\partial p}{\partial T}\right)_v - p\right] dv$$

$$h_2 - h_1 = \int_{T_1}^{T_2} c_p dT + \int_{p_1}^{p_2} \left[v - T\left(\frac{\partial v}{\partial T}\right)_p\right] dp$$

$$s_2 - s_1 = \int_{T_1}^{T_2} \frac{c_v}{T} dT + \int_{v_1}^{v_2} \left(\frac{\partial p}{\partial T}\right)_v dv = \int_{T_1}^{T_2} \frac{c_p}{T} dT - \int_{p_1}^{p_2} \left(\frac{\partial v}{\partial T}\right)_p dp$$

A4. Enthalpy, entropy and internal energy of departure:

$$\frac{(h^* - h)_T}{RT_c} = \int_0^{p_r} \left[T_r{}^2 \left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$

$$\frac{(s^* - s)_T}{R} = \int_0^{p_r} \left[Z - 1 + T_r\left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$

$$\frac{(u^* - u)_T}{RT_c} = \frac{(h^* - h)_T}{RT_c} + T_r(Z-1)$$

A5. Specific heats difference:

$$c_p - c_v = \frac{Tv\alpha_p{}^2}{\beta_T}$$

$$c_p - c_v = R \text{ (for ideal gas)}$$

A6. Some useful calculus relations:

Integration by parts: $\int \spadesuit(\blacklozenge)\clubsuit(\blacklozenge)\, d\blacklozenge = \spadesuit(\blacklozenge) \int \clubsuit(\blacklozenge)\, d\blacklozenge - \int \left[\left(\int \clubsuit(\blacklozenge)\, d\blacklozenge\right) \spadesuit'(\blacklozenge)\right] d\blacklozenge$

Integration of quotient: $\int \frac{\clubsuit'(\blacklozenge)}{\clubsuit(\blacklozenge)} d\blacklozenge = \ln[\clubsuit(\blacklozenge)]$

Differentiation of product $\left(\spadesuit(\blacklozenge)\clubsuit(\blacklozenge)\right)' = \spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) + \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)$

Differentiation of quotient: $\left(\frac{\spadesuit(\blacklozenge)}{\clubsuit(\blacklozenge)}\right)' = \frac{\spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) - \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)}{[\clubsuit(\blacklozenge)]^2}$

Cyclic relation: $\left(\frac{\partial \spadesuit}{\partial \clubsuit}\right)_{\blacklozenge} \left(\frac{\partial \clubsuit}{\partial \blacklozenge}\right)_{\spadesuit} \left(\frac{\partial \blacklozenge}{\partial \spadesuit}\right)_{\clubsuit} = -1$

End of Paper